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RESEARCH REGARDING ECONOMICAL RISKS CAUSED BY ERGONOMICAL ISSUES IN THE WINEMAKING INDUSTRY OF ROMANIA

Cristiana Viorela APREUTESE, Cristina Maria CANJA, Vasile PADUREANU, Anisor NEDELCU, Liliana CECLU

Abstract: *This research investigates the need for ergonomic improvements in Romania's wine-making industry and the economic impact of the ergonomical issues. The study, conducted through case studies in wineries, has its main objective to identify the most encountered ergonomical related problems that can eventually lead to financial problems. This has both the role to increase awareness and proposes solutions to enhance ergonomic solutions throughout the wine-making process. Not only that these solutions could increase the productivity of the workers but ensure sustainable practices in the vineyards and wine factories, and an increase in economic performance. These solutions include elevated grapevine trails, automatic press loaders, automated packaging platforms, and drone vineyard monitoring. This research aims to identify critical ergonomic shortcomings and propose solutions for a more sustainable and worker-friendly wine-making process.*

Key words: *Ergonomics, winemaking industry, financial risk, sustainability, manual labor*

1. INTRODUCTION

If it is to talk about ergonomics or human factors we talk about a scientific topic concerned with the process of understanding the interactions between humans and other elements of a system. This profession implements theories, principles, data and different methods to create to fully optimize human well-being and the overall performance of a system [1].

The East-European country, Romania, boasts a well-established viticulture industry. However, a crucial gap exists between the available technology and its ergonomic implementation in the area due to both economic and sociological reasons. The general infrastructure, of the area is not favorable for the sustainable growth of the small producer.

Even if initially the focus of sustainable development had an ecological perspective, with time was extended towards social and economic aspects [2]. The concepts of ergonomics and sustainable development have the role to evaluate if different activities from the whole industry are efficient within the three dimensions: social, environmental and economic [3].

While the absorption of non-refundable funds from the EU is growing year by year and helps many, it is not enough to implement the newest technology available at every technological step on a large scale, and this is why the manual workforce is the preferred choice.

Some wineries possess modern equipment, however, in the vineyards and in the factories manual labor is preferred both because of cultural and economic reasons, increasing the risk of musculoskeletal disorders (MSDs) among workers.

Musculoskeletal disorders are known to produce a great socio-economic impact, starting with increase costs for all the parts. This applies at the same time to both direct costs and indirect costs, associated with accidents at workplace and occupational disease [4].

MSDs caused by ergonomic factors are directly related to body position, different moves, their speed and frequency, limb position,

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environment related factors such as noise, light, chemicals, vibration, climate, etc. information and operations, visual or perceived information through one of the other senses, as well as the organization at workplace. This last factor implies that tasks are appropriate to the physical condition and skills of the worker [5].

The task of pruning, in the winemaking sector, is currently also associated with increased risk of developing CTDs of the wrist [6]. So, it can be taken into consideration that one of the most important steps in the viticultural process, one without which we couldn't talk about quality wines, represents a critical point when it comes to ergonomic principles. However, industrially established countries have acknowledged the effect of MSDs on workers as the prominent reason for heavy loss in industry and economy [7].

Meanwhile, as we find a focal point on the research of ergonomics, and progresses are made, the medical field with both rehabilitation medicine and occupational medicine allows the introduction of new methods and tools, which could certainly create the context of a decreased occurrence of WMSDs through different measures implemented at primary and secondary levels of prophylaxis [8].

In these case studies, the main ergonomic pain points for small producers of Romania were identified using REBA and RULA methods. The results were then used in the FMEA method to identify the risk priority when it comes to economic failures. At the end of the research, the effects of ergonomic issues in the Romanian vineyards and wineries were highlighted using the Ishikawa Method. However, while the research focuses on small wine producers in Romania, the findings provide insights that may apply to small-scale winemaking operations in similar regions globally.

2. METHODODOLGY

Given the critical role of ergonomics in the winemaking industry, this study employed multiple methods to comprehensively analyze ergonomic challenges and their economic impacts. As stated before, a mixed-method approach was employed. This research utilizes four complex methods to both identify and evaluate ergonomic risks, and their potential effects both on the human workforce, and companies.

This way, not only a comprehensive result be deducted, but both the company side and the worker's side will be covered and taken into consideration to highlight their importance for the conclusion.

2.1 Flowchart Analysis

A detailed flowchart was developed after visiting small producers, mapping the entire winemaking process from vineyard activities to bottling and distribution. Critical control points, where ergonomic risks are most likely to occur, were highlighted.

2.2 REBA and RULA Assessments

Two of the most used evaluation methods when it comes to ergonomic evaluation preferred by researchers are both REBA and RULA methods [9]. For this study, the two methods Rapid Entire Body Assessment (REBA) and Rapid Up-per Limb Assessment (RULA) were conducted. These internationally recognized tools are used to assess worker postures, repetitive movements, and potential for MSDs during various stages of the winemaking process. Questionnaires were administered to workers, and field observations were conducted to gather data for the REBA and RULA analysis [10], [11].

2.3 Failure Mode and Effect Analysis (FMEA)

Expanding upon the ergonomic risks that were discovered, an FMEA study was also carried out. "FMEA is a value-adding process because the team's defined actions improve an organization's knowledge and are subsequently applied as "lessons learned" to future projects of a similar nature" [12]. This approach ranks probable ergonomic-related economic failures according to severity, frequency, and detectability. The selection and application of suitable solutions will be guided by this prioritizing [13].

2.4. Ishikawa Diagram

This method uses a visual tool to identify the root causes of a problem. In this research, the problem encountered is economical challenges experienced by winemakers [14]. By applying these methodologies for the entire process, this study offers a comprehensive picture of ergonomic and economic challenges in Romania's small wineries.

3. RESEARCH RESULTS

3.1 Flowchart analysis

In an area with a great history and culture in winemaking, it's natural that many citizens opted to enter industry, even if at a smaller level, and this is why it's important to understand that both sections presented in Fig. 1 are treated as a whole process in the end. However, for a better understanding of the wine-making process from an ergonomic perspective, starting from the field to fork, the entire task was segmented into a viticultural part and a vinification one.

If in the viticulture sector, the tasks are mainly done outside, in plain heat, rain, or whatever the weather reserves, the vinification and distribution processes take place in a more controlled environment due to a need for controlled temperatures for fermentation and storage. No matter the scale of the production, for each producer, there is a need for a much larger workforce in three technological phases, which are highlighted as high ergonomic risk: pruning, harvesting and crushing, destemming, and pressing. With this increased need for work volume in the context of time pressure, it's essential to prioritize a healthy environment for workers. However, it is important to ensure that each working individual is taken into consideration, as having a business that relies on manual labor implies that the health of workers not only has to be of interest for economic reasons but also from the whole sustainable concept.

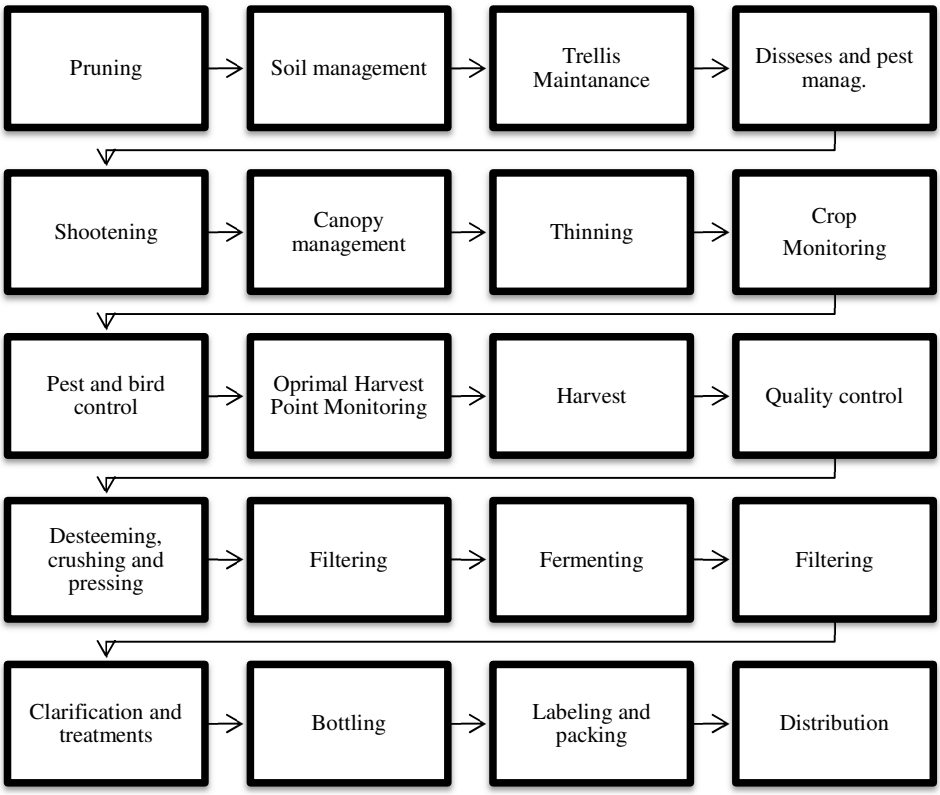

Fig. 1. The winemaking process from start to finish.

Table 1

Ergonomic risk classification.

Step	Ergonomic Risk Level	Movements
Pruning	High	Bending, kneeling, repetitive use of pruning shears
Soil Management	Medium	Walking, operating tractors
Trellis Maintenance	Medium	Reaching, bending, carrying tools
Disease and Pest Monitoring	Medium	Walking through rows, bending to inspect plants
Suckering and Shoottending	High	Bending, kneeling, repetitive twisting and reaching to remove suckers and shoots
Canopy Management	Medium	Reaching, bending, carrying tools
Crop Monitoring	Medium	Walking through rows, bending to inspect grapes
Defoliation (optional)	Medium	Reaching, bending, repetitive movements to remove leaves
Bird Control	Medium	Setting up and maintaining bird netting or other deterrents
Harvest Readiness Monitoring	Medium	Walking through rows, bending to inspect grapes
Harvest	High	Bending, kneeling, lifting heavy grape bins, repetitive picking motions
Quality Control	Medium	Reaching, bending, lifting
Filtration	Medium	Operating valves, monitoring equipment
Fermenting Clarification and treatments	Medium	Reaching and bending for valves
Bottling	Medium	Lifting bottles, repetitive reaching and labeling motions
Labeling and packing	Medium	Lifting boxes, repetitive reaching and packing motions
Distributing	Low	Lifting and carrying boxes

Table 2

REBA and RULA evaluation.

Step	Repetitive Movements	REBA Risk Level	RULA Risk Level
Pruning	Bending, kneeling, repetitive use of pruning shears	Medium	High
Soil Management	Walking, operating tractors	Low	Low
Trellis Maintenance	Reaching, bending, carrying tools	Medium	Medium
Disease and Pest Monitoring	Walking through rows, bending to inspect plants	Low	Low
Suckering and Shoottending	Bending, kneeling, repetitive twisting and reaching to remove suckers and shoots	High	High
Canopy Management	Reaching, bending, carrying tools	Medium	Medium
Crop Monitoring	Walking through rows, bending to inspect grapes	Low	Low
Defoliation	Reaching, bending, repetitive movements to remove leaves	Medium	Medium
Bird Control	Setting up and maintaining bird netting or other deterrents (may involve reaching and bending)	Medium	Medium
Harvest Optimal Point Monitoring	Walking through rows, bending to inspect grapes	Low	Low
Harvest	Bending, kneeling, lifting heavy grape bins, repetitive picking motions	High	High
Quality Control	Reaching, bending, lifting (limited tasks)	Low	Low
Pressing, crushing, Destemming	Bending, kneeling, lifting heavy grape bins, repetitive picking motions	High	High
Filtration	Operating valves, monitoring equipment (may involve some reaching)	Medium	Medium
Fermenting Clarification and treatments	Lifting and carrying ingredients, reaching for valves	Medium	Medium
Bottling	Lifting bottles, repetitive reaching and labeling motions	Medium	Medium
Labeling and packing	Lifting boxes, repetitive reaching and packing motions	Medium	Medium
Distributing	Lifting and carrying boxes (limited tasks)	Low	Low

Every task from the whole technological process, from early spring until distribution in late winter, was evaluated and described in Table 1 that summarizes the most common worker movements identified through a survey of winery employees in Romania throughout the year. The risk level (high, medium, or low) associated with each movement is based on its frequency, duration, and awkwardness.

The results reveal that several tasks involve postures and movements that can lead to MSDs. Pruning and harvesting grapes on low trails, the early spring technological phases, for instance, necessitate prolonged stooping or crouching, placing high strain on the lower back, hips, and knees.

Similarly, operating valves on the most common fermentation tanks or checking low-mounted sensors often require bending at the waist, increasing the risk of lower back pain. For the workers responsible for plowing and applying treatments, the effects of working prolonged times on tractors were observed such as lower back pain. Despite the results showing medium risks, it's imperative to take action to ensure the best work conditions for better productivity.

3.2 Research with REBA and RULA Methods

Once the critical control points of the winemaking process were identified and highlighted on the technological scheme, REBA and RULA methods were applied to obtain a more comprehensive evaluation. While one focuses on the effects on the whole body of the employee, the other focuses mainly on the upper limbs, so the analytic process highlights the complexity of the human body and the effects that repetitive moves have on it.

Table 3

FMEA Analysis.

Risk Factor	Potential Failure Mode	Severity (S) (1-Low, 5-High)	Occurrence (O) (1-Low, 5-High)	Detection (D) (1-Easy, 5-Difficult)	Risk Priority Number (RPN) = S x O x D
Awkward postures (vineyard activities - pruning, suckering, etc.)	MSDs leading to increased medical expenses, absenteeism, and worker turnover	4	4	3	48
Repetitive movements (vineyard & winery activities - pruning, harvesting, bottling, etc.)	MSDs leading to increased medical expenses, absenteeism, and worker turnover	4	4	2	32
Manual lifting (grape bins, tanks)	MSDs leading to increased medical expenses, absenteeism, and worker turnover, potential worker compensation claims	5	3	2	30
Exposure to chemicals (treatments)	Respiratory problems, skin irritation leading to medical expenses and absenteeism	4	2	4	32
Reaching for high valves/shelves	Slips, falls leading to potential injuries,	4	2	3	24

	medical expenses, and absenteeism				

3.3 Application of FMEA Analysis

Since small producers heavily depend on manual labor, any workforce loss directly impacts production and profits. To prevent this, high-risk tasks were identified, and risk factors were grouped using FMEA, helping producers address potential economic challenges from ergonomic issues. Knowing which of the previously mentioned are the main risk factors, it's essential to address the problem and to offer solutions.

Starting with ergonomic training on proper lifting, carrying, and bending techniques and with providing tools with improved grips. Moreover, the training offered to workers improves efficiency and contributes to reduced execution time. By introducing more short breaks at shorter intervals of time, instead of usual breaks had shown that workers are more efficient at work [9]. Educating the workforce with different training courses to improve efficiency and at the same time for a reduced time of process execution affects the amount of energy invested and labor as the work process is completed faster [10].

Other solutions to implement are investing in lifting equipment (hoists, forklifts) for heavy loads and exploring the option of implementing gravity-fed systems for grape movement in the wineries or for the upcoming producers, designing the factory in such a way that tractors or any other transportation can directly overthrow the grapes into the pressing machines.

Task variations and rotation are obligatory, short breaks for stretching are a must, the same as switching to ergonomic workstations for bottling and packaging. Investing in elevated ramps for fermentation tasks could decrease the necessity of bending to monitor the parameters.

3.4 Application of Ishikawa Method

The results obtained from the previous methods show the main ergonomic problem small producers could encounter is MDS caused by repetitive movements, equipment design, work characteristics, and environmental factors. Furthermore, if not addressed, this could lead to financial risks for winemakers. Fig. 2 showcases the cause-effect diagram for the process (based on [14]).

It can be observed that one of the main elements that leads to the economic failure of small wine producers in the ergonomic context are work characteristics such as low grapevine trails requiring prolonged stooping postures during pruning and harvesting. This system is implemented in most of the cultivated areas, especially in Romania. Only the new implemented cultures adopted a higher Vertical Shoot Positioning (VSP) however, other wine producer countries like Italy already changed it with time with higher, more ergonomic efficient trellis.

Manual harvesting is also a work characteristic frequently present in Romania's vineyards, alongside with long work hours during peak season, both in the spring and at harvesting times. Repetitive movements including spring tasks (pruning, shearing bonding, and shooting), or late summer, early autumn ones (manual lifting of heavy grape crates, frequent bending over to check fermentation tanks with bottom-mounted valves and sensors), and equipment design are high contributors to the problem.

Flexor and extensor hand and fingers muscles are continuously used during these technological steps however the entire muscular system of the upper limb is solicitated. The equipment also plays one of the most important roles in the frequency and severity of medical-related time-off of the workers. Also, it is one of the easiest and most effective changes to implement, as technology in this field is continuously evolving.

Sensor placements, or even fermentation tanks placements can make the difference between repetitive bending movements during the fermentation period of wines and an ergonomic posture. While automating bending tools aren't an innovation, for small producers with limited finances, it can help attract work force, as the classical way using only the hands is one of the reasons people tend to stay away

from the small vineyards. Same thing goes with the automated shearing tools. It also can be mentioned that environmental factors tend to have a great impact on the general health of workers.

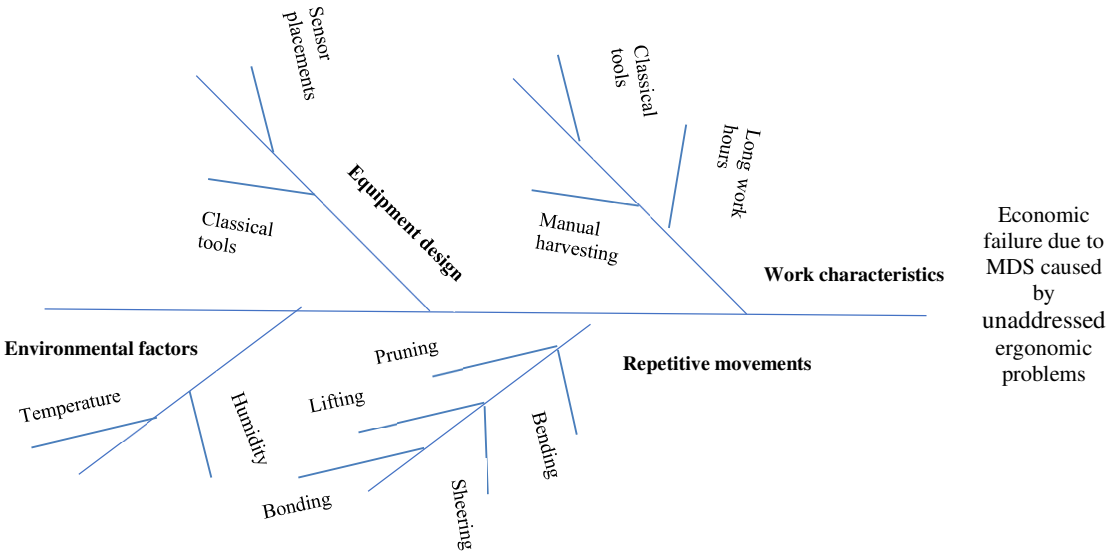

Fig. 2. Ishikawa diagram resulted.

Many tasks must be done in a certain timeframe, and this implies long hours in either colder temperatures, for pruning, and bonding, or the opposite, working long hours in the heated sun, at constant temperatures over 25 Celsius.

Bottled wine has a decreased risk of spoilage linked to temperature and humidity fluctuations; however, the storage units must obtain lower temperatures, even in summer, which can lead to a thermic shock as in Romania, year by year the maximum registered temperatures exceed the previous years.

3.5 Innovative Solutions for Small Producers

To address the significant risk factors contributing to musculoskeletal disorders (MSDs) in Romanian vineyards, five targeted solutions can significantly mitigate the risk of economic failure due to labor-related inefficiencies. By implementing these strategies, vineyard operations can ensure both worker safety and sustained economic performance.

Drone Technology for Vineyard Scouting and Targeted Treatments. One of the most impactful interventions is the use of drones for vineyard monitoring and precise application of treatments. Drones can perform tasks such as scouting for pest infestations, disease monitoring, and assessing vine health, which would otherwise require manual labor over large areas. This reduces the time and physical strain placed on workers while enhancing the precision of applied treatments. By minimizing worker exposure to potentially harmful chemicals during pesticide application, and temperature and sun exposure, drones contribute to better health outcomes for employees and reduce absenteeism due to work-related illnesses. Drones also offer a scalable solution, with small producers benefiting from reduced operational costs as drone technology becomes more affordable.

Automated Harvesting and Elevated Trellises to Reduce Bending. Manual harvesting is one of the most labor-intensive processes in viticulture and involves repetitive bending, leading to a high incidence of lower back and joint-related disorders among workers. Transitioning from manual harvesting to automated systems can drastically reduce the physical burden on laborers. Automated grape harvesters can perform the task efficiently

without the need for repetitive bending, thus significantly reducing MSDs. Coupled with elevated trellises, which allow vines to grow at a height that eliminates the need for workers to stoop, these technological advancements can prevent chronic injuries associated with traditional harvesting methods. Additionally, elevated trellis systems enhance the ease of mechanization, allowing vineyards to adopt automated or semi-automated systems at various stages of the production cycle.

Self-Propelled and Remotely Operated Tractors. The use of self-propelled or remotely operated tractors for essential vineyard tasks such as plowing, spraying, and harvesting offers a significant reduction in manual labor. These tractors eliminate the need for workers to physically manage machinery over extended periods, which is associated with fatigue and an increased risk of accidents. By allowing remote operation, vineyards can maintain efficiency while minimizing worker exposure to potentially hazardous tasks. Moreover, the adoption of such technology aligns with sustainable vineyard practices, as these tractors can be designed for energy efficiency and equipped with sensors to optimize resource use such as water and fertilizers. In Romanian vineyards, where manual labor still dominates, the gradual integration of such technology could lead to long-term health benefits for workers, lower operational costs, and increased productivity.

Gravity-Fed Systems for Winery Design. The redesign of wineries to include gravity-fed systems for grape movement represents another critical ergonomic intervention. Gravity-fed systems rely on the natural force of gravity to move grapes between stages of production, eliminating the need for manual lifting and transferring of heavy grape bins. In traditional winemaking setups, workers frequently handle and lift heavy loads, which can lead to back injuries and strain-related disorders. Implementing a gravity-fed system not only reduces the physical demands placed on workers but also enhances production efficiency by streamlining the transfer process. This system is particularly beneficial for small producers who may not have access to large mechanized systems but can still achieve ergonomic improvements through thoughtful design changes.

- **Adjustable Workstations for Bottling and Packaging.** In the final stages of wine production, bottling and packaging tasks often require repetitive motions such as lifting, reaching, and labeling, which can lead to upper limb disorders. Implementing adjustable workstations allows employees to modify the height and positioning of their workspace to suit their ergonomic needs. Properly designed workstations can reduce strain on the back, shoulders, and wrists, promoting better posture and reducing the risk of developing MSDs [15]. Adjustable workstations also improve worker satisfaction and productivity by creating a more comfortable and efficient working environment. For Romanian vineyards, particularly those expanding their production capacity, ergonomic workstations present a cost-effective solution to reduce long-term health issues associated with repetitive tasks.

4. CONCLUSION

Balancing tradition and worker well-being is essential for the sustainability of Romania's small vineyards. This research highlights the significant ergonomic risks associated with manual labor in small-scale wine production. By identifying these risks and proposing solutions, this study addresses the need for improved working conditions that can reduce the prevalence of musculoskeletal disorders (MSDs) and enhance overall productivity.

The economic impact of these ergonomic challenges is particularly severe for small producers, who rely heavily on manual labor. Due to both economic and sociological factors, such as limited financial resources and a deep-rooted cultural reliance on traditional farming practices, many small producers have not yet adopted the latest technological advancements in the wine industry.

While larger vineyards have been able to invest in mechanized solutions, smaller

producers struggle to afford these innovations, resulting in continued worker strain and reduced efficiency. Therefore, small producers face higher operational costs due to worker injuries, absenteeism, and lower productivity, which further hinders their ability to invest in new technology.

The solutions proposed in this study, such as the implementation of drones for vineyard monitoring, automated harvesting systems, and adjustable workstations, offer viable pathways to alleviate these ergonomic challenges. However, the economic reality for many small producers means that adopting these technologies will require significant initial investment, which is currently beyond their reach.

Therefore, policy interventions, such as government subsidies or EU funding, could play a crucial role in enabling small vineyards to access these technologies. By reducing the financial barriers to technological adoption, small producers can improve their working conditions, boost productivity, and ensure long-term economic sustainability.

In conclusion, addressing the ergonomic challenges in Romania's wine industry is not only a matter of improving worker health but also of ensuring the economic viability of small vineyards. Without interventions that support the adoption of new technologies, small producers will continue to face the dual burden of worker injuries and inefficiencies, which threaten their ability to compete in a growing and increasingly mechanized global wine market.

The integration of ergonomic solutions, backed by financial support, holds the key to a more sustainable and prosperous future for Romania's small wine producers.

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Cercetări privind riscurile economice cauzate de problemele ergonomice în industria vinificației

Această cercetare investighează necesitatea îmbunătățirilor ergonomice în industria viti-vinicolă din România și impactul economic al problemelor ergonomice. Cercetarea, realizat prin studii de caz în crame, are ca obiectiv principal identificarea celor mai întâlnite probleme ergonomice care pot conduce la eventuale probleme financiare. Acesta are atât rolul de a crește nivelul de conștientizare, cât și de a propune soluții pentru îmbunătățirea problemelor ergonomice pe parcursul procesului de vinificație. Aceste soluții nu doar că ar putea crește productivitatea lucrătorilor, dar ar asigura și practici durabile în podgorii și fabricile de vin, precum și o creștere a performanței economice. Aceste soluții includ sisteme elevate pentru viță de vie, încărcătoare automate pentru prese, platforme automate de ambalare și monitorizarea podgoriilor cu drone. Această cercetare își propune să identifice deficiențele ergonomice critice și să propună soluții pentru un proces de vinificație mai durabil și mai prietenos pentru lucrători.

Cristiana Viorela APREUTESE, PhD student, Transilvania University of Brasov, Faculty of Manufacturing Engineering, cristiana.apreutese@unitbv.ro, 29 Eroilor Boulevard, 500036 Brasov, Romania.
Cristina Maria CANJA, PhD., Associate Professor, Transilvania University of Brasov, Faculty of Food and Turism**,** canja.c@unitbv.ro**,** 29 Eroilor Boulevard, 500036 Brasov, Romania.
Vasile PĂDUREANU, PhD., Professor, Transilvania University of Brasov, Faculty of Food and Turism**,** padu@unitbv.ro**,** 29 Eroilor Boulevard, 500036 Brasov, Romania.
Anisor NEDELCU, PhD., Professor, Transilvania University of Brașov, Faculty of Technological Engineering and Management, a.nedelcu@unitbv.ro, 29 Bulevardul Eroilor, 500036 Brașov, Romania.
Liliana CECLU, PhD., Associate Professor, Bogdan Petriceicu Hasdeu University of State, Faculty of Economics, Engineering and Applied Sciences, ceclu.liliana@usch.md, 1 Independence Square, MD-3909 Cahul, Republic of Moldova